

UNDERWATER WELDING

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ABSTRACT

This paper enlightens about the use of varied, exaggerated & intensive manufacturing tool “welding” under the water, which was formerly just used in the atmospheric fabrication works only. By the advent of special waterproof electrodes, the engineers proved to the world that one can also perform all the welding operations in the presence & continuous water. It also laid to repair or sometimes to replace the underwater structures, offshore structures which may get fail soon at the deeper water level. It also encompassed the use of various underwater welding techniques & some other new technologies which are emerging up in the field of underwater welding like: Automation welding.

KEYWORDS: Underwater Welding, Emergency Repair Works, Types, Principle of Operation, Techniques of Performing the Underwater Weldments, Inspection Techniques, Future Scope, and New Emerging Technologies

INTRODUCTION

Now a days in all the fabrication works welding has become a very important tool. The application of welding has become so varied and extensive that it would be no exaggeration to say that there is no metal industry and no branch of engineering that doesn't involve the use of welding as a manufacturing tool. As per the application to requirement, the similar welding processes can be applicable within the atmosphere. But if one wants to do the welding below water then these processes would not be applicable, since, they are not designed for that application. Hence underwater welding came into existence. At the offshore structures, underwater platforms and all the marine applications where there is a presence of water or there is a continuous contact of water called splash zone, it is a major concern.

The main difficulty which is faced is due to continuous corrosion of underwater structures, it is necessary to repair them continuously or to replace them with another one. Under water welding has now become an important tool in the fabrication industry for joining the steel on the offshore platforms, under water structures, pipelines, ships and in many other applications. The underwater structures of after getting corrode away there are chances that they will get fail at the deeper water level and the maximum failure is at shallow depth. So the repair works and welding jobs at these levels is a most technologically challenging task.

HISTORY

Underwater welding began during the worldwar1 when the British navy officers used it to make the temporary repairs on the ships. These repairs consisted of leaking rivets of the ship hulls. Earlier the underwater welding was restricted to salvaging operations and the emergency repair works only. Also it was limited to the depth of 10 meters only. As underwater welding process consisted of use of special water proof electrodes which were developed in the year 1946 by: 'Vander willigen'. During the early stage of the underwater welding, it was just applied to weld and patch so that repair work would be performed. As the time passed and more experience was gained, the ambitious individuals and the companies joined the forces to improve the results and to establish achievable specifications.

What is the Area of Use of Under Water Welding

The Underwater Welding has been used for:

- New construction and installation of offshore structures, subsea pipelines and harbor facilities.
- For maintenance and repair works
- The repair works include the damage caused by fatigue and accidents offshore and oil platforms.
- Repair works and sometimes replacement of damaged subsea pipelines-sections, repairing of holes in the ship's hull or
- Corrosion damage to the harbor facilities.
- Mostly used for repairing work of ships, offshore oil platforms and pipelines.

Commonly Materials Being Welded by Underwater Welding

Includes- Steel, Stainless Steel, Copper, Aluminum.



Figure 1: Welder / Diver

Welder/Diver

For performing the task of underwater welding accurately and of very high quality, welder must have sufficient qualification and experience too. Welder/diver is a certified welder who is also an commercial diver and capable of performing tasks associated with commercial subsea work, weld setup and preparation and has the ability to weld in accordance with AWS D3.6 specification for underwater welding and cutting and other related activities. Welder/diver qualifications and experiences required for the given work always vary from one project to another. Most of the welding contractors require their welding/diver to be 'jack of all trades' means that the welder/diver must be capable of performing underwater cutting, rigging, inspection, maintenance and photography in addition to underwater welding.

CLASSIFICATION OF UNDERWATER WELDING

The Underwater welding can be classified into 2 categories

Welding in the WET Environment

This method is primarily intended for temporary repair works, emergency repair works and salvage operations in the shallow water. This type of welding results in the poor quality of welds which will not last longer. It is a very cheap & economical method. By this method due to the electrolysis of water, pockets of hydrogen & oxygen gases are created. Also it leads to inferior weld qualities like increased porosity, reduced ductility, Hydrogen embrittlement. Weld metal is quickly quenched by the seawater. This method is used when the time and money are short and the function needs to be

maintained. Wet welding is carried out at ambient water pressures with the welder/diver in the water using waterproof electrodes with no barrier present in between welding rod and the one which is being welded.

Welding in the DRY Environment

Welding in the dry environment influences the method of creating a chamber without the influence of water and carrying out welding process. This method is a very convenient method since the resultant welds are very strong, long lasting. Dry welding results in the highly improved performance of the welding process and hence high quality of welds can be obtained compared to the wet welds. The chamber in the dry welding is filled with the breathable gas at a prevailing pressure. Welding in the dry environment is categorized into:-

Hyperbaric Welding

Dry hyperbaric welding was discovered by Russian metallurgist- konstain khrenov in 1932. In hyperbaric dry welding, a chamber is sealed around the structure to be welded and is filled with the breathable gas at a prevailing pressure. This method provides the high quality weld joints that meet radiography and code requirements. The chamber is sealed into the structure and filled with the mixture of 90-95% helium and 5-10% oxygen. Here the bottom portion of the chamber is exposed to open water and is covered by grating to equalize the chamber pressure to the outside sea water pressure at a certain depth. The chamber provides the welder/diver with all the necessary equipments required for the welding in a dry environment.

Cofferdam Welding

It is an type of dry welding in which welding is carried out in dry in the air, where the rigid steel structure to house the welders is sealed against the side of the structure to be welded and is open to the atmosphere. Other than the steel, plywood and rubberized canvas or any other suitable material can be used. The weld chamber used is so designed and custom built to accommodate the braces and other structural members whose centerlines may intersect at or near the area that is to be welded. The size, dimensions and configuration of the weld chamber depends upon the area that must be encompassed and no. of welders that must be working in chamber at same time for achieving the state of dry welding, high pressure must be achieved by preparing the enclosure to be filled with the Helium gas under high pressure for pushing back the water and the welder being supplied with breathing mask and protective equipments. The greatest advantage is that: the weld metal is not in contact with the water which is accomplished by evacuating the chamber by the displacement of water by air or suitable gas mixture. Another advantage of the dry welding are: incremental in the stable welding operation, reduction in the hydrogen problem, lower quench rate of weld and base metal and restoration of weld strength and ductility. Welding is performed in the chamber, immune to ocean currents and marine animals. The warm, dry habitat is well illuminated and has its own environmental control system. The disadvantage of the dry welding are: large quantities of the complex equipments are required for which chamber is extremely complex. Chamber once used can't be used for another one.



Figure 2: Welding in the DRY Environment-Hyperbaric and Cofferdam

PRINCIPLE OF OPERATION

Mainly it includes the power source. The power source as AC should not be used since it will continuously fluctuate and will not quickly respond to the welding operations. Hence DC power source should be selected with 300-400 amperes rating and with negative electrode. The DC current machine should always be grounded to ship. The welding circuit includes the knife switch which is operated on the surface by the assistant upon the signal of welder/diver. The main reason for the use of the knife switch is that it cuts off the welding current. For gripping the electrode, electrode holder with the twisted head is utilized. All the types of electrode holders are extra insulated against water electrode types used conform to AWS E-6013 classification. The electrodes must be thoroughly insulated, waterproofed so that the water will not come in contact with the metal parts. The work lead is attached with 3 feet from the point of welding & is perfectly insulated to avoid leaks.

UNDERWATER WELDING TECHNIQUES

There are many under water welding techniques which may differ in accordance to the surrounding environment of the weldments. The surrounding environment may be a wet or dry one. Generally, dry hyperbaric welding involves the processes like: SMAW(Shielded Metal Arc Welding), FCAW(Flux Cored Arc Welding), GMAW(Gas Metal Arc Welding), & PMAW(Plasma Metal Arc Welding), FW(Friction Welding), and LBW(Laser Beam Welding) etc. these processes could be operated at hyperbaric pressures but can differ in accordance to the water head. Of these, TIG (Tungsten Inert Gas) welding process is the most commonly used. Similarly, for wet under water welding, SMAW is most commonly employed. Let's have a look on all these welding techniques.

Shielded Metal Arc Welding (SMAW)

The shielded metal arc welding also referred to as conventional metal arc welding or metal arc welding uses an arc struck between work piece and the shielded filler metal electrode. This process makes use of either AC or DC power source. The coated electrode performs the following functions:

- To facilitate the establishment and maintenance of arc.
- To protect the molten metal from oxygen and nitrogen of air by producing the shield of gas around arc & weld pool.
- To provide the formation of slag so as to protect the welding seam from rapid cooling.

Shielded metal arc welding makes the use of heavily coated electrodes which are used to obtain high quality weldments. Heavy coatings are composed of: ionizing chalk, deoxidizing Aluminum, gas generating starch, slag forming kaolin, alloying & binding materials. Electrodes for the shielded metal arc welding (SMAW) are classified by AWS as E6013 and E7014.

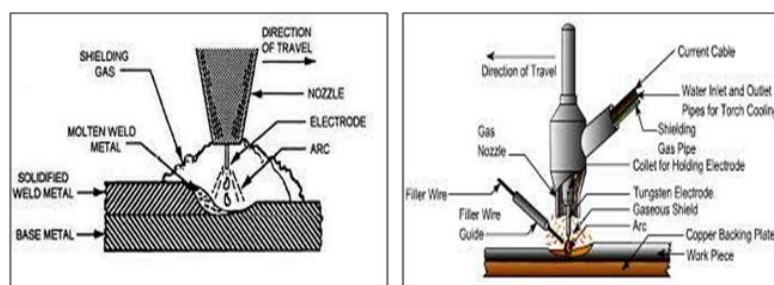


Figure 3: Shielded Metal Arc Welding (SMAW) Figure 4: Tungsten Inert Gas (TIG) Welding

Tungsten Inert Gas (TIG) Welding

This arc welding process uses an intense heat of electric arc between non consumable tungsten electrode and material to be welded. For TIG, the nonfusing temperature resistant tungsten electrode in addition to welding torch, energy source and inert gas is a major factor for obtaining optimum results. The inert gas such as Helium or Argon or the mixtures of both are used for the shielding effect.

Argon is more widely used than Helium because it is heavier gas producing better shielding at lower flow rate. Shielding gas prevents the contamination of weld metal against Oxygen & Nitrogen present in the air. When filler metal rod is used, it is usually fed manually into the weld pool. Electrodes used in this process are made from Tungsten & their alloys only to generate the arc. Torch used in this process directs the shielding gas and welding power to arc and holds the electrode. A constant current welding power supply produces the energy which is conducted across arc through the column of highly ionized gas & metal vapors called plasma.

Inert gas supplied to weld area through the water cooled electrode holder provides the protective shield around arc. This type of welding is commonly used for welding thin sections of: S.S, & nonferrous metals such as Al, Mg & Cu alloys.

Let's refer to the following table:

Table 1: Tungsten Welding Electrodes

Name of Electrode	Composition	Colour Code	Properties	Standardization	Application
Pure tungsten.	99.5% Tungsten.	Green.	High consume rate, provides good arc stability.	AWS-EWP.	AC sine wave welding.
Lanthanated tungsten electrode (1% black or 1.5% lanthanum).	97.5% Tungsten + 1.30-1.70% Lanthanum.	Black.	Excellent arc starting, low burn off rate, good stability & excellent ignition characteristics.	AWS-EW La-1.5	AC or DC both.
2% Ceriated, Tungsten electrode.	98% Tungsten + 2% cerium.	Grey.	For low operation welding.	AWS-EW Ce-2	Excellent in DC welding.
1% Zirconated Tungsten electrode.	99.10% Tungsten + 0.80 % Zirconium.	White.	Produces extremely stable arc & resists tungsten splitting, high resistance to contamination.	AWS-EW-Zr-1	AC welding.
2% Thoriated Tungsten electrode.	97.30% Tungsten + 1.70-2.20% Thorium.	Red.	Preferred for longevity. Thorium increases electron emission qualities of electrode, high current carrying capacity.	AWS-EW-Th-2	DC welding.

Flux Cored Arc Welding (FCAW)

Flux cored arc welding is a semi-automatic or automatic arc welding process. This process requires continuously consumable tubular electrode containing flux, constant current welding power supply & externally supplied shielding gas is often used. Flux is used to generate the necessary protection from the atmosphere. This welding produces the flux that must be removed. The advantage of this type of welding process are: smooth, uniform welds having good contour, flexibility, good quality of welds & high welding speed. Also the use of stick electrodes used in SMAW is unnecessary. This process is used for welding of Mild & Low alloy Steels, S.S, High nickel alloys.

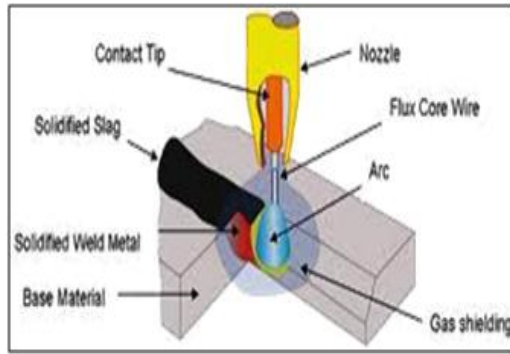


Figure 5: Flux Cored Arc Welding (FCAW)

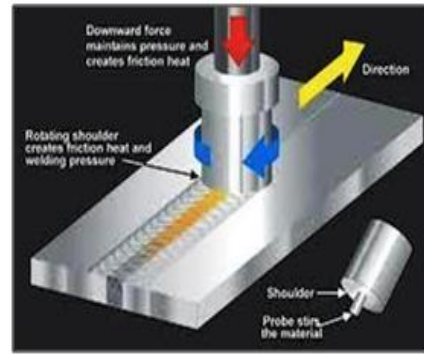


Figure 6: Friction Welding (FW)

Friction Welding (FW)

Friction welding is a solid state welding in which heat required to join the two metal parts is obtained by friction between ends of the parts are abruptly braked. The parts to be joined. This process consists of the following steps:-

- Here two parts are axially aligned to each other whose one of the part to be welded is rotated at about 3000 RPM.
- The second part is made advanced to the rotating part to rub against it.
- To cause the friction between two parts, slight axial pressure is applied between two parts. Due to this the temperature at the interface will increase allowing them to soften & hence formation of forged joint.
- After the sufficient heating has taken place, the power drive is disconnected & the axial pressure is increased to forge the two parts together.

By this type of process, high quality welds can be obtained and there are no chances of distortion or warping. Even semiskilled operators can also be employed.

NEWER TECHNIQUES FOR UNDERWATER WELDING

Robot Welding and Robotic Spot Welding

A welding process that contain repetitive task on similar pieces might be suitable for automation. Here the welding is performed & controlled by the robotic equipment. Robotic spot welding is a cost effective choice compared to manual spot welding. Robotic spot welding can reach difficult weld areas with the consistent reliability. By the advent of robotic spot welding, a valuable floor space will be saved.

During the welding process by use of robots, the cables & hoses used for current and air tend to limit the movement of robot wrist. Here the robot can repeatedly move the welding gun to each weld location & position it perpendicular to the weld seam. Spot welding robots have 6 or more axes of motion & capable of approaching the points in work envelope from any angle. This permits the robot to be flexible in positioning a welding gun to weld an assembly. Generally for robot welding, GMAW is most preferable.

WHY AUTOMATION WELDING?

The most prominent advantage of robot welding is precision & productivity. Robot welding improves the weld reliability. Once programmed correctly, the robots will perform the repeated tasks at same dimensions & specifications. It decreases the error potential and hence decreased scrap and rework and increased output.

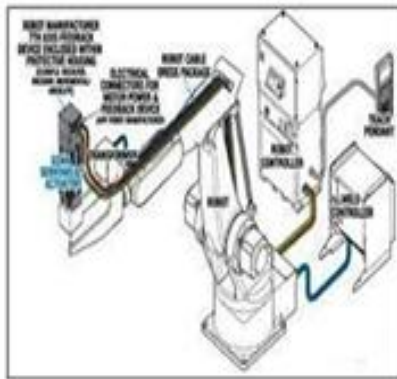


Figure 7: Robot Welding

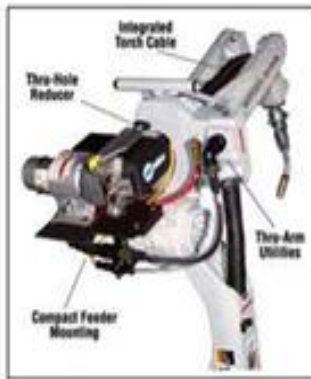


Figure 8: Robot Spot Welding



Laser Beam Welding (LBW)

It is an type of radiant energy welding process that uses the laser beam to melt and vaporizes the material upon which welding is being performed. Laser beams are very high electromagnetic energy density electron beam which are highly coherent, monochromatic and unidirectional. By focusing the beam on spot, beam will get concentrated producing the high power density.

The energy produced is enough sufficient to melt & vaporizes the work metal in a very short time and thus permitting fusion with another metal. Here the lasing material used is in the form of solid ruby rod which is doped with chromium and with the end faces made parallel to each other. One end of the rod is made totally reflective and other end is made partially reflective at about 80%.

A number of xenon flash lamps are placed around laser rod for pumping it in to the excited state. A highly reflective cylindrical enclosure surrounds both rods & flash lamps to restrict the light from pump into the rod. The action of laser is based on the following well known principle: “If an atom or molecule of lasing material is raised to the energy level E_2 by an outside source like light, heat or chemical reaction, it doesn't stay permanently over there at that state. Later on it decays back to its stable lower energy level E_1 releasing photon of light.”

The frequency of light emitted will greatly depend upon difference in energy levels ($E_2 - E_1$) and plank's constant. If photon of light so released comes into contact with another atom or molecule or higher energy level E_1 , releasing another photon of light.

The two photons so generated are identical in wavelength, phase, direction & energy. This sequence of triggering is multiplied many fold to produce the laser beam. Hence, when the ruby crystal consisting of Aluminum Oxide into which 0.05% chromium has been introduced is pumped to excited state by the series of xenon flash bulbs, the chromium atom are raised to higher energy level, releasing the stream of photons and fall back to their stable lower energy level.

When this light is reflected from the end mirrors it triggers more atoms to their ground state leading to chain reaction of stimulated radiation. Some of this light escaping from partially reflecting mirror on right constitutes the laser. Because of its highly monochromatic nature, this light can be easily focused & concentrated with lens to very small diameter spot with much higher intensity. The great advantage of this type of welding is that the laser beam can melt & vaporizes any known metal and there is no requirement of flux or filler material. Also, the process is easily automated and production rate is also fairly high.

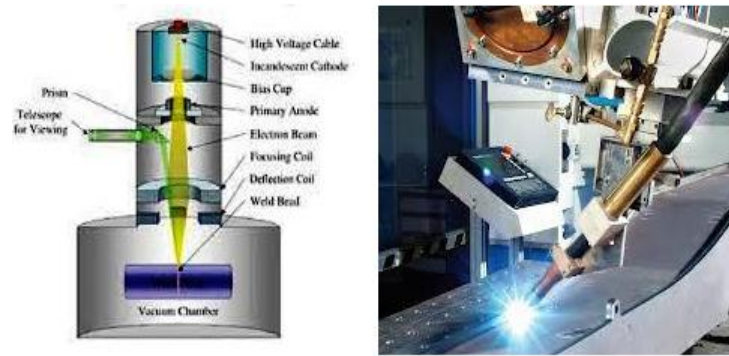


Figure 9: Laser Beam Welding (LBW)

UNDERWATER INSPECTION

Underwater inspection includes the visual photographic examination of the various underwater structures and repairs and NDE such as Magnetic Inspection (MI), Ultrasonic Inspection (UI) and Radiographic Inspection (RI). In the typical underwater inspection the underwater inspector is equipped with the light and camera. In order to carry out the proper visual and NDT check, blast cleaning has to be carried out to remove all the seawater organisms that grow on the underwater structure. Latest development in the underwater inspection is the use of ROV's. These machines are operated by an ROV pilot.



Figure 10: Welder/ Diver Performing Underwater Inspection by NDT Method

RISKS INVOLVED

There are some risks which are involved during the underwater welding which are mentioned below:-

Electric Shock: There is a possibility of electric shock when the equipment is not properly insulated, or when the power supply is not shut off immediately when the welder terminates the arc during welding.

Explosion: Arc welding produces the hydrogen and oxygen. Pockets of gases can build up and are potentially explosive.

Nitrogen Narcosis: A health hazard normally experienced by divers during the diving activity when the safety stops at certain level is not adhered to. Curiously, the risk of drowning is not listed with the hazards of underwater welding.

For the welded structures, inspection of welds after welding may be more difficult than welds made above water. There is a risk of defects that may remain undetected and may cause failure in the long run.

SAFETY RULES

Some necessary precautions should be carried out such as:

- Follow employer's safety practices.
- Fumes and gases can be hazardous to your health.
- Arc rays can injure eyes and skin.
- Use adequate ventilation while welding.
- Wear suitable eye protection and protective clothing. Do not touch live electrical parts.
- Wear rubber gloves.
- Only change the electrode, when it is cold.

SCOPE FOR THE FURTHER DEVELOPMENT

Now-a-days, wet metal arc welding technique is carried out for the underwater welding but the qualities of welds are not much good due to the hydrogen embrittlement. Presently, the research work is carried towards the automation in which robots are used for underwater welding & allied activities. Their examples are: THOR-1(TIG-Hyperbaric Orbital Robot) is developed where the diver performs the pipe fittings, installs the track and orbital head on pipe and the rest of the process is automatic.

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